

## **Final Technical Report**

NASA Grant: NAG5-12058

Principal investigator: John T. Wasson

Funding period 05/01/02--04/30/03

## **Cosmochemical Studies: Meteorites and their parent asteroids**

### **Summary of the research**

During this period our research was mainly focused on three topics: formation of iron meteorites, formation of chondrules and the possibility that large aerial bursts have left a geological record.

We list below 7 papers that received significant support from this grant. The first three papers were mainly written with the support of a previous NASA grant, but they still required moderate amounts of effort to complete the publication process. The last four papers were prepared during the period of this grant.

### **Formation of iron meteorites and other metal rich meteorites**

During the previous grant period we presented new data on iron meteorites in the groups earlier called IAB and IIICD, and showed that our new and more precise data required a complete reassessment of the classification. We ended up with one large main group and six satellite subgroups. We called this mélange the IAB complex. We presented evidence and arguments indicating that these irons were formed by impact processes.

The Rubin et al. (2002) paper shows that a new ungrouped, silicate-rich IAB-complex iron named NWA 468 contains low-Ca clinopyroxene and hence quenched from high temperatures. This is consistent with it having formed by impact-melting processes. Its similar composition to lodranites suggests that these meteorites formed by related processes.

The Bencubbin meteorite consists of centimeter-size metal and silicate lumps. The bulk composition is roughly chondritic, and there are fragments of ordinary and carbonaceous chondrites found within the structure. The most common explanation of its formation is the impact alteration of chondritic materials. Rubin et al. (2003) described Gujba, the first observed fall of a Bencubbin-like meteorite. They showed that the metal nuggets have a range of FeS contents, and that the volatile element contents are correlated with these variations.

Pallasites are stony-iron meteorites that seem to have formed at the interface between the mantle and the core of an asteroid. The Wasson and Choi (2003) paper is the most detailed study of the main-group pallasites (PMG) ever published. Data are presented for 12 elements in 33 pallasite samples. As also concluded earlier, the PMG seem to have formed in the same asteroid as the IIIAB irons. A new proposal is that the high Ge and Ga concentrations in some PMG metal and the high fayalite contents of some PMG olivine may reflect reaction with a magmatic gas phase.

The Cook et al. study of Pt, Re and Os isotopes in IIAB and IIIAB irons was mainly supported by grant funds belonging to Rich Walker at the Univ. of Maryland. Wasson'

provided some of the samples based on his previous studies of their trace element compositions. The new isotopic and elemental concentration data show that the two groups of irons formed very early, about 4.5 Ga ago, and are generally consistent with fractionation by fractional crystallization together with variable amounts of melt trapping.

### **New perspectives on the formation of chondrules**

We consider the Wasson and Rubin (2003) paper on overgrowths on chondrule relict grains to be of major importance. Our evidence indicates that the final melting events recorded in chondrules produced only thin, ca. 5  $\mu\text{m}$  overgrowth layers on olivine and pyroxene grains, and thus indicate that cooling was much more rapid than the values commonly quoted by those who model chondrule melting/cooling with furnace experiments.

In the Chizmadia et al. (2002) paper we described amoeboid olivine inclusions (AOI), chondrule-like objects that formed in melting events that predated the formation of normal chondrules. We also established a new metamorphic/alteration classification scheme for CO3 chondrites based on the progressive development of fayalitic rims on forsterite grains in AOI.

### **Consequences of large aerial bursts**

The most famous impact event in modern history is the Tunguska, Siberia, event that occurred in 1908. An impactor released all of its kinetic energy in the atmosphere, producing an explosion (an aerial burst) that was the equivalent of a very large nuclear weapon. Wasson (2003) suggests that aerial bursts orders of magnitude larger than Tunguska have occurred in the past. Because these do not make craters, the chief geological record of their occurrence may be silicate melt that has chilled to glass. The layered tektites of Southeast Asia and the Libyan Desert may be such a record.

### **Papers supported by this grant**

- Rubin A.E., Kallemeyn G. W. and Wasson J.T. (2002) A IAB-complex iron meteorite containing low-Ca clinopyroxene: Northwest Africa 468 and its relationship to lodranites and formation by impact melting. *Geochim. Cosmochim. Acta* **66**, 3657-3671.
- Chizmadia L. J, Rubin A. E.. and Wasson J. T. (2002) Mineralogy and petrology of amoeboid olivine inclusions: Evidence for CO3 parent-body aqueous alteration. *Meteorit. Planet. Sci.* **37**, 1781-1796.
- Wasson J. T. and Rubin A. E. (2003) Ubiquitous relict grains in type-II chondrules, narrow overgrowths, and chondrule cooling rates following the last melting event.. *Geochim. Cosmochim. Acta* **67**, 2239-2250.
- Wasson J. T. (2003) Large aerial bursts; an important class of terrestrial accretionary events. *Astrobiology* **3**, 163-179.
- Rubin A.E., Kallemeyn G. W., Wasson J.T. Clayton R. N., Mayeda T. K., Grady M., Verchovsky A. B., Eugster O and Lorenzetti S.. (2003) Formation of metal and silicate globules in Gujba: A new Bencubbin-like meteorite fall from Nigeria. *Geochim. Cosmochim. Acta* **67**, in press.
- Wasson J. T. and Choi B.-G. (2003) Main-group pallasites - chemical composition, relationship to IIIAB irons, origin. *Geochim. Cosmochim. Acta* **67**, in press.

Cook D. L., Walker R. J., Horan M. F., Wasson J.T. and Morgan J. W. (2003) Pt-Re-Os systematics of group IIAB and IIIAB iron meteorites. *Geochim. Cosmochim. Acta*, **67**, in revision.

#### **Patents and Inventions**

No patents were obtained by our research group during the time covered by this proposal nor were an inventions produced.